

**Looking for extra-dimensions
at the weak-scale
experimental search for
Kaluza-Klein states signatures
at the e^+e^- linear colliders**

Linear Collider Workshop

Sitges 1st May, 1999

Marc Besançon

(DAPNIA/SPP/CEA Saclay)

Some motivations

Exciting piece of superstrings physics !

- string dualities \rightarrow string scale M not at M_{Planck}
 - Witten $\rightarrow M$ arbitrary parameter
 - Lykken $\rightarrow M$ in the TeV region ?
- superstrings lives in 10-d space time
- possibility of "opening" δ extra-dimensions at the TeV scale

See also Antoniadis 90' (string compactification)

Impact on phenomenology

- Grand Unification at TeV scales
Dienes, Dudas, Ghergetta
- Millimeter ranges forces
 $\delta = 2 \rightarrow \frac{1}{r^4}$ ($< \text{mm}$)
 $\delta = 6 \rightarrow \frac{1}{r^8}$ ($< \text{fm}$)
 Antoniadis, Arkani-Hamed, Dimopoulos, Dvali ...
- Excitation of Kaluza Klein states at colliders
 Antoniadis, Benakli, Quiros
 Hewett
 Mirabelli, Perelstein, Peskin
 Giudice, Rattazzi, Wells
 Han, Lykken, Zhang
 Rizzo
- More recently \rightarrow growing activity in various fields:
 (Susy and EW breaking, Deep Inelastic Scattering,
 FCNC, neutrino mass, μ magnetic moment, Fermi
 constant, cosmology...)
 Delgado, Pomarol, Quiros, Masip
 Mathews, Raychaudhuri, Sridhar
 Faraggi, Pospelov
 Dienes, Dudas, Gherghetta
 Graesser
 Nath, Yamaguchi
 Arkani-Hamed, Dimopoulos, Kaloper, March-Russell
 ooooooooooooooooooooo

KK graviton emission in the extra-dimension

$e^+e^- \rightarrow \gamma$ graviton, from hep-ph/9811291
WITHOUT ISR:

$$\frac{d\sigma}{dx_\gamma d\cos\theta} = \frac{\alpha}{64} \frac{2\pi^{\frac{\delta}{2}}}{\Gamma(\frac{\delta}{2})} \left(\frac{\sqrt{s}}{M}\right)^{\delta+2} \frac{1}{s} f(x_\gamma, \cos\theta)$$

with $x_\gamma = \frac{2E_\gamma}{\sqrt{s}}$ and assuming $\sum_{k_T} = R^\delta \int d^\delta m$
M = scale and δ = number of extra-dimensions
divergence for $x_\gamma \rightarrow 0$ and $\cos^2\theta \rightarrow 1$

1st task: add ISR \rightarrow

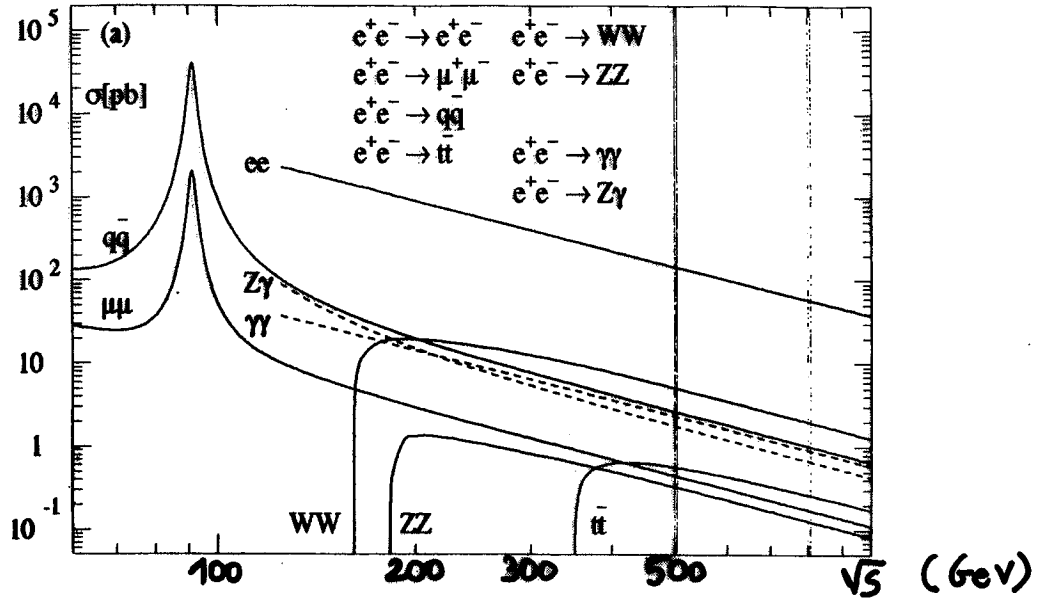
lowering of Xsection up to 10% or more !

look for signature $(\gamma)_{ISR} \gamma \not{E}$

Updates since Oxford workshop

- Change event generators:
 BHWIRE for bhabha
 NUNUGPV for $\nu\nu\gamma(\gamma)$
- Use a fast detector simulation package:
 SIMDET 3.1
- Simplification of the selection
 better control of bhabha
 $e^+e^- \rightarrow \gamma\gamma(\gamma)$ no more a problem

σ	$(e^+e^- \rightarrow \nu\nu\gamma(\gamma))$	=	9.72	pb	NU NU GFV
σ	$(e^+e^- \rightarrow e^+e^-\gamma(\gamma))$	=	14.7	nb	BN Wine
σ	$(e^+e^- \rightarrow Z\gamma)$ also $Z \rightarrow \nu\bar{\nu}$	=	8.2	pb	} PYTHIA 5.7
σ	$(e^+e^- \rightarrow ZZ)$	=	0.55	pb	
σ	$(e^+e^- \rightarrow WW)$	=	7.7	pb	
σ	$(e^+e^- \rightarrow W\gamma)$	=	5.3	pb	
σ	$(e^+e^- \rightarrow Zee)$	=	7.4	pb	
σ	$(e^+e^- \rightarrow \gamma\gamma(\gamma))$	=	8.02	pb	
σ	(2 photons)	=	3.6	nb	



SIMDET 3.1

*** Detector parameters used for simulation :

*** CCD (2 cm) :

acceptance (cos(theta) central region)	= 0.928000
impact parameters (r-phi, central region)	= 0.0058 0.0159 mm
impact parameters (r-z, central region)	= 0.0058 0.0159 mm
acceptance (cos(theta) forward region)	= 0.961000
impact parameters (r-phi, forward region)	= 0.0126 0.0156 mm
impact parameters (r-z, forward region)	= 0.0126 0.0156 mm

*** Tracker :

mag. field	= 3.00 Tesla
total length of TPC	= 5.00 m
radius of TPC	= 1.70 m
p-trans. minimum	= 0.05 GeV
track reconstruction eff.	= 0.99
charge misinterpretation prob.	= 0.005 0.015
acceptances (cos(theta)):	
for overall tracker system	= 0.996195
for TPC	= 0.978148
theta and phi resolutions	= 0.001 0.001
for p-t resolution -- see sr SITRAK	

*** Electromagnet calorimeter :

min. deposited energy	= 0.10 GeV
electron misinterpretation prob.	= 0.01
acceptance (cos(theta))	= 0.996802
granularity (cell size)	= 0.9 degrees
energy resolution parameters	= 0.102 0.006

4.5°

*** Hadron calorimeter :

min. deposited energy	= 0.20 GeV
average energy deposited by muons	= 3.80 GeV
acceptance (cos(theta))	= 0.996802
granularity (cell size)	= 2.0 degrees
energy resolution parameters	= 0.405 0.042

*** Add. forward tracker :

p-trans. minimum	= 0.20 GeV
acceptance (min / max cos(theta))	= 0.996195 0.906308
angular resolution parameters	= 0.00010 0.00010
for p-t resolution -- see sr SIFWTR	

*** Forward muon tracker :

min. energy of muon	= 5.00 GeV
muon tracking efficiency	= 0.95
charge misinterpretation prob.	= 0.003
acceptance (min / max cos(theta))	= 0.996195 0.978148
angular resolution parameters	= 0.001 0.001
for energy resolution -- see sr SIFWMU	

*** Instrumented mask :

min. energy of particle	= 10.00 GeV
acceptance (min / max cos(theta))	= 0.999962 0.996802
for more details -- see sr SIMASK	

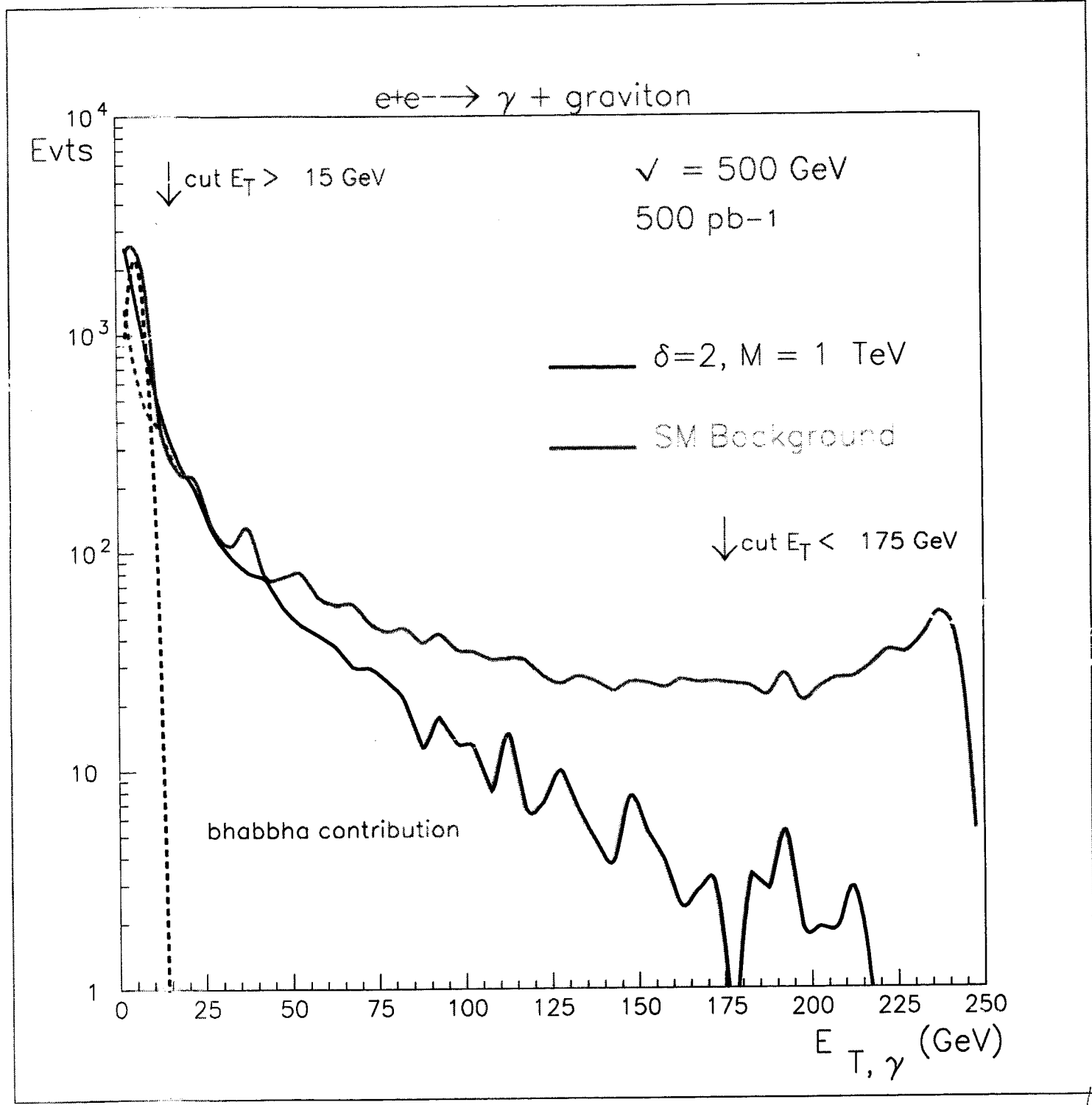
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SELECTION

- Take information from the "BEST" record of SIMDET 3.1
i.e. best estimate for object's energy and direction
- Candidate γ defined by a detected object having zero charge and zero mass
- Ask for only one candidate γ

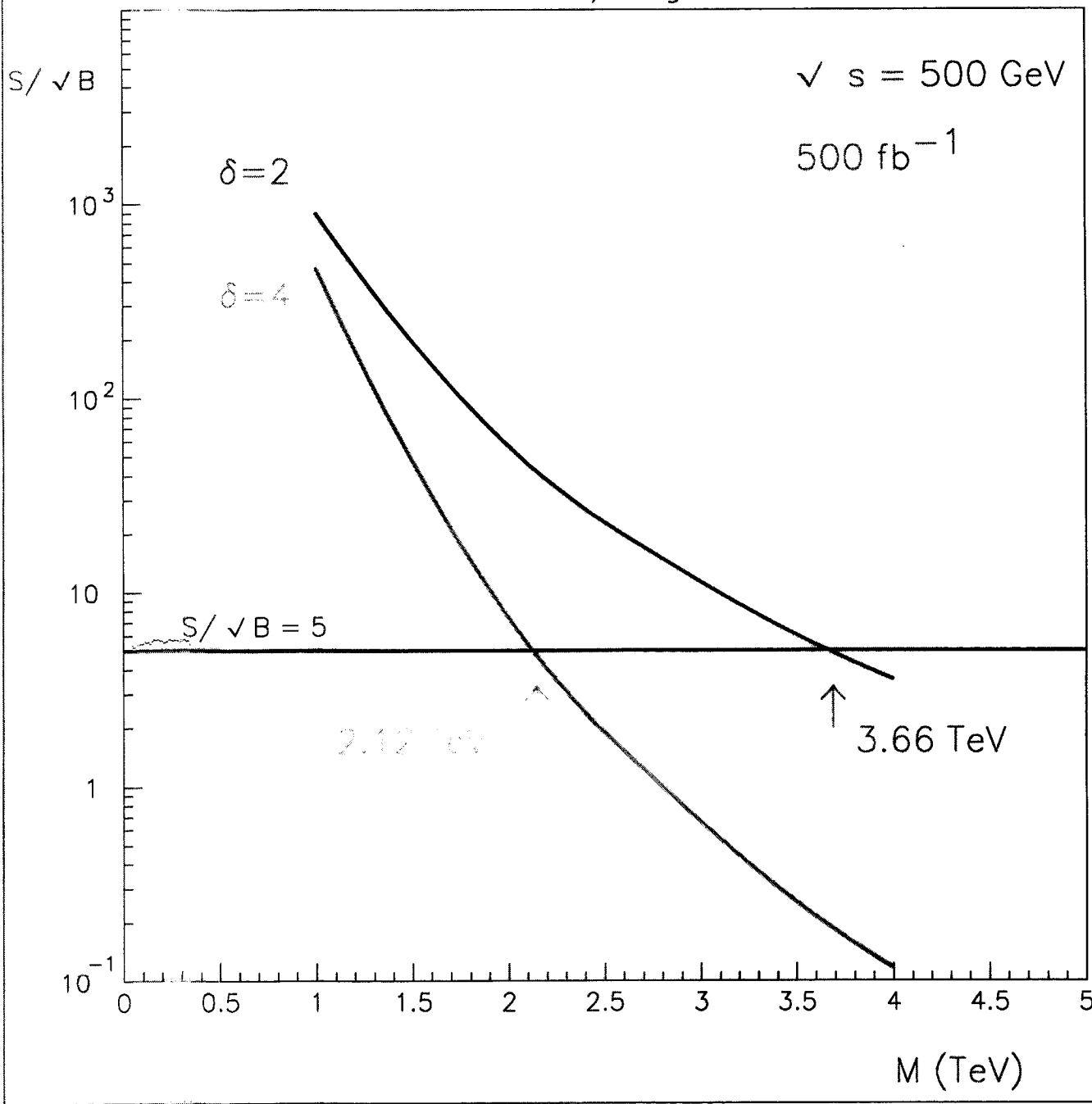
Look at E_T of this candidate γ

M. Besaucou



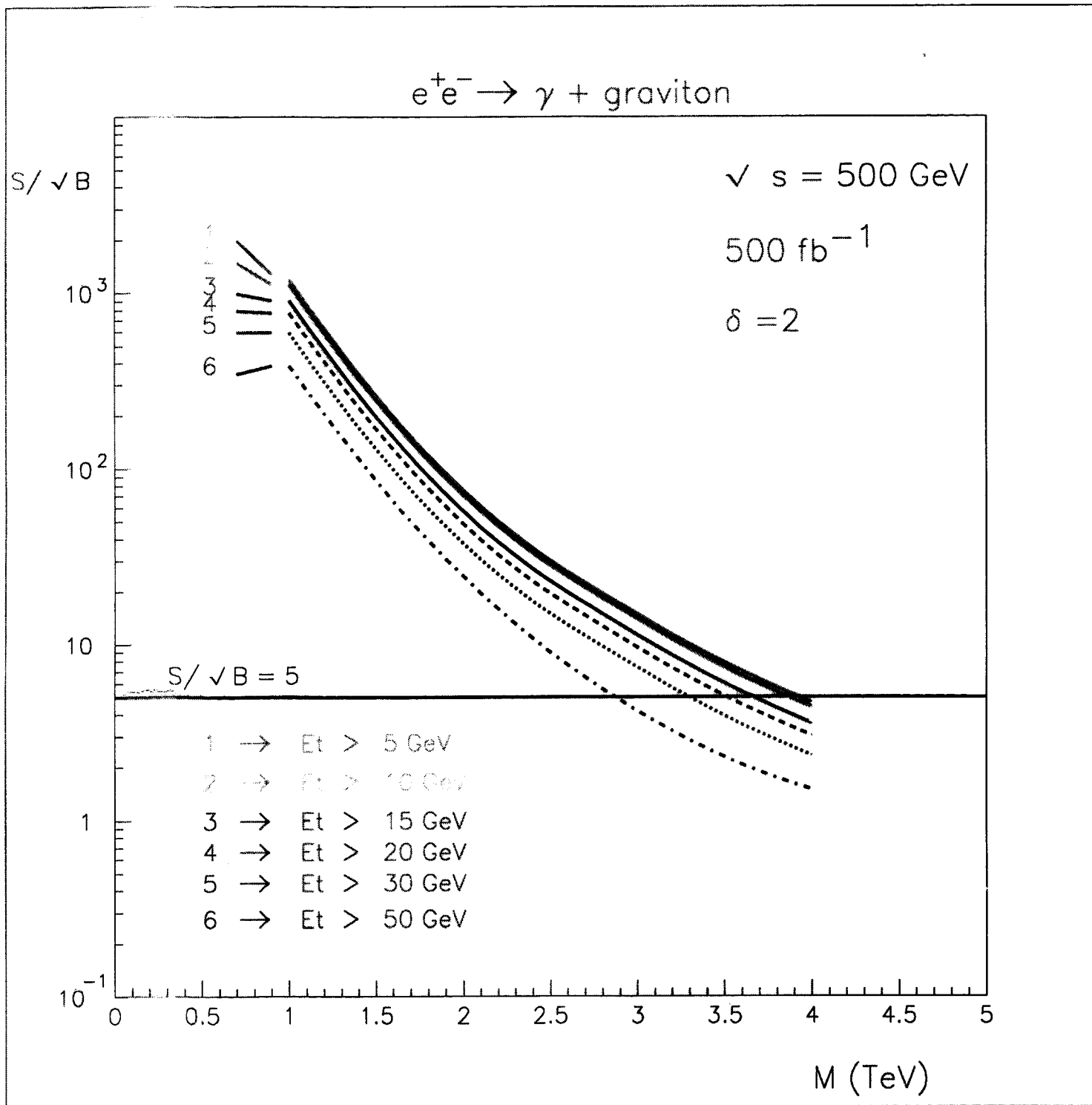
M. Besaucon

$e^+e^- \rightarrow \gamma + \text{graviton}$



DELPHI MORIOND 93'

$M \gtrsim 1.2 \text{ TeV}$



Conclusions

- The search for Kaluza-Klein states at present/future colliders is an exciting piece of (experimental) string physics !
- At the e^+e^- collider the search for $e^+e^- \rightarrow \gamma$ graviton seems a promising way to look for extra-dimensions at the TeV scale
- Xsection have been calculated
inclusion of ISR \rightarrow Xsections are 10% -15% lower
- From the present Monte Carlo study including fast detector simulation this signal can be "extracted" from the $\nu\bar{\nu}\gamma(\gamma)$ background
- Explore the 3.5 - 4 TeV string scale domain for 2 extra-dimensions at the linear collider after $500 fb^{-1}$
To be studied next: gain on sensitivity with beam polarization
- Comparison with LHC γ channel vs. monojet channel ?
- Additionnal direct search for Kaluza-Klein states signatures can be provided by the search for $e^+e^- \rightarrow Z$ graviton where the $SU(2)$ gauge boson Z decays as usual into quarks or leptons giving 2 jets or 2 leptons + missing energy

$$e^+e^- \rightarrow \gamma + \text{graviton}$$

$\sqrt{s} = 500 \text{ GeV}$

